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ABSTRACT

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an instructional design for accelerating children's concept learning

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WISCONSIN RESEARCH
AND DEVELOPMENT
CENTER FOR
COGNITIVE LEARNING

Technical Report No. 321

AN INSTRUCTIONAL DESIGN FOR ACCELERATING CHILDREN'S CONCEPT LEARNING

by

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Report from the Project on
Conditions of School Learning and Instructional Strategies

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AN INSTRUCTIONAL DESIGN FOR ACCELERATING CHILDREN'S CONCEPT LEARNING

Following the lead of industrial psychologists (e.g., Folley, Farriman, & Jones, 1960; Miller, 1953, 1962), a number of educational psychologists are investigating the nature of the instructional process (e.g., Gagné, 1970; Gilbert, 1962; Glaser, 1965; Glaser & Resnick, 1972). This effort has resulted in the development of new methods for analyzing learning tasks and specifying the content of learning.

As originally conceived by the military, task analysis is a process that identifies the characteristics of a task in terms of the component behaviors and knowledge that underlie the learning of the task. Gagné (1962) extended the work of Miller (1953) and others by proposing a method of task analysis that has become a prototype in the fields of educational research and instructional development. According to Gagné (1962), learning tasks can be divided into subordinate knowledge components by asking the question, "What kind of capability would an individual have to possess if he were able to perform the task successfully, were we to give him only instruction [p. 356]?" When this question is asked of each newly identified capability, a hierarchy of skills related to the final task is eventually established.

While a review of the literature of task analysis procedures (Bernard, 1975) revealed a substantial number of studies that used task analysis procedures to teach sets of related skills (Gagné, 1968; Gagné & Brown, 1961; Kingsley & Hall, 1967; LeFrancois, 1968; Resnick, Siegel, & Kresh, 1971; Resnick, Wang, & Kaplan, 1973), few studies were found that employed a task analysis approach in designing instruction to teach concepts associated with specific subject-matter areas taught in the classroom. The concern of the present research is with concepts that are defined in terms of specific informational or content attributes (e.g., peninsula, tree, noun) rather than with process concepts that are considered to generalize across subject-matter areas (e.g., conservation, identity, seriation).

An instructional design based on task analysis procedures has been formulated by Klausmeier, Ghatala, and Frayer (1974) to develop lessons to teach subject-related concepts. The instructional design involves the following: (1) analysis of the concept to be taught, (2) specification of the level at which the concept is to be attained and of the cognitive operations that underlie the learning of the concept at that particular level, and (3) identification of instructional strategies that facilitate attainment of the concept.

Klausmeier, Ghatala, and Frayer (1974) have shown that many concepts can be attained at four distinct, hierarchical levels of abstractness and inclusiveness: Concrete, Identity, Classificatory, and Formal. The Conceptual Learning and Development (CLD) Model identifies the cognitive operations that are involved in learning the same concept at each of the four levels of attainment. The CLD Model was used to fulfill the requirements of the second phase of the instructional design in the present study.

The purpose of the present study was to determine whether school-age children can attain a subject-matter concept at a level higher than that normally attained through the use of written instructional lessons based on the instructional design just described.

METHOD

Instructional Design

The concept selected for analysis and instruction was equilateral triangle. Analysis of the concept resulted in the identification of the following relevant information: (1) the definition of the concept--a plane, closed, and simple figure with three straight sides of equal length and three equal angles; (2) the defining attributes of the concept--plane figure, closed figure, simple figure, three straight sides of equal length, and three equal angles; (3) irrelevant attributes of the concept--size, spatial orientation, and color; (4) examples of the concept that might be used in instruction--equilateral triangles that vary systematically across irrelevant attributes; and (5) nonexamples of the concept that might be used in instruction--geometric figures that share all defining attributes but one and some or all irrelevant attributes with equilateral triangles.

It was decided to teach to the Formal level of concept attainment as indicated by the CLD Model. The CLD Model specifies four cognitive operations that are prerequisites for Formal level concept learning: the learner must be able to attend to things, discriminate one thing from another thing, remember the discriminated thing, and generalize that two or more forms of the same thing are equivalent in some way. Additionally, a learner must be able to perform the following relevant operations in order to acquire a concept at the Formal level: discriminate and label the defining and irrelevant attributes of the concept, hypothesize the relevant attributes, remember hypotheses, evaluate hypotheses using examples and nonexamples of the concept, and infer the concept.

Several instructional strategies which were identified as being facilitative of Formal level concept learning were used in this study: use of definition (Anderson & Kulhavy, 1972; Feldman & Klausmeier, 1974), empirical selection of concept examples through an instance probability analysis (Woolley & Tennyson, 1972), use of rational sets of examples and nonexamples (Feldman, 1972; Markle & Tiemann, 1969; Swanson, 1972), pairing of examples and nonexamples (Houtz, Moore, & Davis, 1973; McMurray, 1974; Tennyson, Woolley, & Merrill, 1972), emphasis of relevant attributes (Rasmussen & Archer, 1961), teaching of a strategy (Bourne, 1966), feedback (Clark, 1971), and active involvement by the student (Piaget, 1964).

Subjects

One hundred and thirty-nine fourth grade students from six classrooms in two elementary schools participated in the study; the schools were located in two small rural Wisconsin communities. Twenty-one of these students were absent from school on one or more days during the four-day study and those students were eliminated from the final sample, yielding a total of 118 subjects. Grade level was selected on the basis of the results of a previous study (Klausmeier, Sipple, & Allen, 1974); in that study the Formal level of the concept equilateral triangle was not attained by samples of fourth grade students from two different school populations.

Materials

Two instructional lessons, Lessons 1E and 2E, were developed to teach the concept equilateral triangle; two placebo lessons dealing with the concepts of number systems and curves, Lessons 1C and 2C, were also developed. Lesson 1E taught subjects to discriminate and label the defining attributes of the concept (three straight sides of equal length, three equal angles, plane figure, closed figure, and simple figure). The teaching of the attributes and labels followed this sequence: first, a list of words which the students might not have previously encountered was read aloud; second, each defining attribute and label was defined and illustrated through the use of examples and nonexamples; third, subjects were requested to illustrate each attribute by connecting figures outlined in dots; and fourth, subjects were shown figures and were instructed to indicate whether each figure had a particular defining attribute. Immediate feedback indicated to each subject whether his or her answer was correct as well as the rationale behind the answer.

Lesson 2E taught subjects to evaluate examples and nonexamples of the concept equilateral triangle based on defining attributes which were presented in a definition. In the first part of Lesson 2E, a review of the previous day's material was given and a definition of the concept was presented and explained. Students were then instructed to draw several examples of the concept equilateral triangle using the defining attributes presented in the definition. The second part of Lesson 2E presented two rational sets of paired examples and nonexamples which were found in a previous instance probability analysis to represent a range from difficult to easy; that is, the percentage of correct responses by fourth grade students on a test requiring identification of examples and nonexamples of equilateral triangles given only the definition ranged from just above a chance level (difficult items) to almost 100 percent (easy items). Also, explanations of why particular geometric figures were or were not equilateral triangles were provided in this part of the

lesson. Finally, in the third part of the lesson, subjects were taught a strategy to associate the five defining attributes of the concept in a conjunctive fashion. This part of the lesson contained exercises and feedback in evaluating examples and nonexamples. The strategy involved presenting five questions which the subjects needed to answer in order to formally evaluate whether a geometric figure was a member of the class equilateral triangle. The following is a sample question:

> Remember, your job is to tell if the figure is an equilateral triangle. Be sure to circle Yes or No after each of the five questions. Then circle Yes or No after the question: Is it an equilateral triangle?
>
> 1. Does it have three straight sides of equal length? Yes No
> 2. Does it have three equal angles? Yes No
> 3. Is it a plane figure? Yes No
> 4. Is it a closed figure? Yes No
> 5. Is it a simple figure? Yes No
>
> Is it an equilateral triangle? Yes No

Students determined that a figure was an equilateral triangle when all five questions could be answered affirmatively.

Lesson 1E and 1C each contained 23 pages and required 35 minutes to complete. Lessons 2E and 2C were each 19 pages long and required 25 minutes to complete. The Dale-Chall Formula for Predicting Readability (Dale & Chall, 1948) was used to ensure that the reading difficulty of all four lessons was appropriate for fourth grade students. In addition, a pilot study was carried out with ten fourth grade students in order to determine appropriateness of the reading level, approximate time requirements, clarity of instructions, and interest level. Several minor changes in the wording and content were made in the lessons as a result of the pilot.

Criterion Instruments

The Conceptual Learning and Development Assessment Series I: Equilateral Triangle (Klausmeier, Ingison, Sipple, & Katzenmeyer, 1973) consists of ten tests and was used as a pretest and a posttest to assess the students' mastery of equilateral triangle at the Classificatory and Formal levels of concept attainment. The Classificatory test consisted of eight items, each progressively more difficult as determined by the visual similarity of examples and nonexamples. Five of the items instructed subjects to "put an X on the things on the right that have exactly the same shape (equilateral triangle) as the one on the left."

Each of these items contained four to ten examples and nonexamples of equilateral triangles. The last three items each presented five examples and five nonexamples of the concept and instructed subjects to "put an X on the things below that have exactly the same shape."

The Formal test consisted of the following: a five-item Discriminating Attributes subtest that required students to discriminate defining attributes, a seven-item Vocabulary subtest to assess their knowledge of the labels for the concept and each defining attribute, a five-item Evaluating Examples subtest that required students to evaluate examples and nonexamples based on defining attributes, and a Definition subtest to assess their recognition of the concept definition.

A placebo pretest designed to assess knowledge of grammatical and numerical concepts was also developed. Each placebo pretest item was parallel in form to an item on the Klausmeier et al. 1973 assessment. The assessment measures required 15 minutes to complete.

Procedure

On the first day of the study, each subject received either the pretest or the placebo pretest. General instructions as well as directions for answering each item were read aloud by the experimenter. Subjects were instructed to read verbal response alternatives silently and to indicate their response by circling the letter next to the correct answer.

On the second day, subjects received either Lesson 1E or Lesson 1C and were instructed to read the lesson silently. At the beginning of the session, the experimenter read aloud with the subjects the word list which appeared in both lessons.

On the third day, all subjects who had read Lesson 1E on the previous day received Lesson 2E; all subjects who had read Lesson 1C on the previous day received Lesson 2C. Subjects were instructed to read their lessons silently.

On the fourth day, all subjects received the posttest. General instructions as well as directions for answering each item were read aloud by the experimenter.

During the four days, the experimenter answered only those questions that dealt with the instructions or with the pronunciation of words. Communication among subjects within each classroom was controlled as follows: students were encouraged not to communicate with others about the lessons; each teacher was asked to remind students not to talk about the experiment; and during the four sessions, students worked individually and their questions were answered on an individual basis.

Experimental Design

Previous investigators (cf. Beilin & Franklin, 1962; Sigel, 1968; Smedslund, 1961) have expressed the need to control for the self-instructional effects of repeated administrations of learning and assessment tasks. As a result, a variation of the Solomon Four-Group design

(Campbell & Stanley, 1963) was employed to determine the effects of the experimental lessons and to control for any possible effects of the pretest. The 139 students were randomly assigned to one of the following groups: Experimental Group 1 received the pretest and the two experimental lessons, Control Group 1 received the pretest and the two placebo lessons, Experimental Group 2 received the placebo pretest and the two experimental lessons, Control Group 2 received the placebo pretest and the two placebo lessons. All groups received an immediate posttest as well as a retention measure administered two months later.

RESULTS

Subjects received either a score of 1 (passing) or a score of 0 (not passing) on both the Classificatory and Formal tests depending on the number of items correctly answered. At the Classificatory level, subjects were required to answer correctly at least seven of the eight items in order to pass. Formal level mastery was demonstrated when subjects passed each of the four Formal subtests. Passing criteria for these subtests were as follows: correctly answering four of the five Discriminating Attributes items, five of the seven Vocabulary items, four of the five Evaluating Examples items, and the Definition item. These passing criteria were adopted from a previous study which used the same posttest (Klausmeier, Sipple, & Allen, 1974). Table 1 presents the number and proportion of subjects who passed the Classificatory and Formal levels and the Formal subtests.

Data were analyzed using chi-square tests of homogeneity. Comparison of the Classificatory level pretest scores for Experimental Group 1 and Control Group 1 and Classificatory level posttest scores for Control Group 1 and Control Group 2 indicated that the pretested groups were initially equivalent and that communication between groups during the four days of the study did not have an effect ($\chi^2 = .50$, $df = 2$, $p < .05$).

An overall chi-square test at the Classificatory level revealed significant differences among the groups ($\chi^2 = 12.33$, $df = 3$, $p < .05$). When all pairwise comparisons at this level were examined using a chi-square analog to Scheffé's procedure (Maraschuilo, 1971), significant differences were found between Experimental Group 2 and Control Group 2 and between both control groups ($p < .05$). All differences were in favor of the experimental groups. On the overall Formal test ($\chi^2 = 36.48$, $df = 3$, $p < .01$), significant differences in favor of the experimental groups were observed between Experimental Group 1 and Control Group 1 and between Experimental Group 2 and Control Group 2 ($p < .01$). A summary of the simple and complex post-hoc comparisons for both the posttest data and the two-month retention data is presented in Table 2.

Chi-square tests of homogeneity conducted on each of the four Formal subtests revealed significant differences among the groups (all $ps < .01$): Discriminating Attributes ($\chi^2 = 11.89$, $df = 3$), Vocabulary ($\chi^2 = 49.58$, $df = 3$), Evaluating Examples ($\chi^2 = 36.69$, $df = 3$), and Definition ($\chi^2 = 38.36$, $df = 3$). When pairwise comparisons on the Discriminating Attributes

TABLE 1

NUMBER AND PROPORTION OF SUBJECTS WHO PASSED THE CLASSIFICATORY AND FORMAL LEVELS ON THE POSTTEST

Test	Treatment Group			
	Exp. 1 (N=32)	Con. 1 (N=30)	Exp. 2 (N=28)	Con. 2 (N=28)
Classificatory	30(.94)	22(.73)	26(.93)	18(.64)
Formal (overall)	19(.60)	2(.07)	18(.64)	3(.11)
Discriminating	31(.91)	22(.73)	26(.93)	16(.57)
Vocabulary	24(.75)	5(.17)	23(.82)	3(.11)
Evaluating	20(.62)	7(.23)	22(.79)	3(.11)
Definition	21(.66)	4(.13)	20(.71)	4(.14)

TABLE 2

SUMMARY OF SCHEFFÉ POST-HOC COMPARISONS:
POSTTEST AND RETENTION

Test	Comparisons							
	Exp. 1 Con. 1	Exp. 1 Exp. 2	Exp. 1 Con. 2	Exp. 2 Con. 1	Exp. 2 Con. 2	Con. 1 Con. 2	E&C 1 E&C 2	E 1&2 C 1&2
Classificatory								
Posttest	NS	NS	$p<.05$	NS	$p<.05$	NS	NS	$p<.05$
Retention	NS	NS	NS	NS	$p<.05$	NS	NS	$p<.05$
Formal (overall)								
Posttest	$p<.01$	NS	$p<.01$	$p<.01$	$p<.01$	NS	NS	$p<.01$
Retention	$p<.01$	NS	$p<.01$	$p<.01$	$p<.01$	NS	NS	$p<.01$
Discriminating								
Posttest	NS	NS	$p<.01$	NS	$p<.01$	NS	NS	$p<.01$
Retention	NS	NS	NS	NS	NS	NS	NS	$p<.01$
Vocabulary								
Posttest	$p<.01$	NS	$p<.01$	$p<.01$	$p<.01$	NS	NS	$p<.01$
Retention	$p<.01$	NS	$p<.01$	$p<.01$	$p<.01$	NS	NS	$p<.01$
Evaluating								
Posttest	$p<.01$	NS	$p<.01$	$p<.01$	$p<.01$	NS	NS	$p<.01$
Retention	$p<.01$	NS	$p<.01$	$p<.01$	$p<.01$	NS	NS	$p<.01$
Definition								
Posttest	$p<.01$	NS	$p<.01$	$p<.01$	$p<.01$	NS	NS	$p<.01$
Retention	$p<.01$	NS	$p<.01$	$p<.01$	$p<.01$	NS	NS	$p<.01$

subtest were examined, a significant difference in favor of the experimental group was found between Experimental Group 2 and Control Group 2. In addition, the two experimental groups performed significantly better than the two control groups. On the Vocabulary, Evaluating Examples, and Definition subtests, significant differences in favor of the experimental groups were observed between Experimental Group 1 and Control Group 1 and between Experimental Group 2 and Control Group 2 (all $ps < .01$). There was no effect of pretesting at the Formal level.

Retention

Ten subjects were lost from the sample over the two months between the posttest and the retention test (four from Experimental Group 1, one from Control Group 1, three from Experimental Group 2, and two from Control Group 2). Table 3 presents the performance of the four groups on the two-month retention test. Significant differences were found among the groups on both the Classificatory test ($\chi^2 = 12.78$, $df = 3$, $p < .05$) and the Formal test ($\chi^2 = 23.70$, $df = 3$, $p < .01$). On the Classificatory test, significant differences in favor of the experimental group were found between Experimental Group 2 and Control Group 2 as well as between the performance of both experimental groups and that of both control groups. On the overall Formal test the following significant differences were observed: Experimental Group 1>Control Group 1, Experimental Group 1>Control Group 2, Experimental Group 2>Control Group 2. On the Discriminating Attributes subtest, the only significant difference was found between the performance of both experimental groups and that of both control groups. When all pairwise comparisons were conducted on the Vocabulary, Evaluating Examples, and Definition data, the following significant differences between groups were observed for each of the subtests: Experimental Group 1>Control Group 1, Experimental Group 1>Control Group 2, Experimental Group 2>Control Group 1, Experimental Group 2>Control Group 2 (all $ps < .01$).

DISCUSSION

Results at the Classificatory level on the posttest suggest that the experimental lessons designed to teach concepts at the Formal level were extremely effective in bringing almost all of the experimental subjects to the Classificatory level who were not at this level previously. This finding validates one of the basic principles of the Conceptual Learning and Development Model specified by Klausmeier, Ghatala, and Frayer (1974)--that mastery of a concept at the Classificatory level precedes Formal level mastery. It appears that the pretest did influence the performance of subjects in Control Group 1. These subjects demonstrated mastery at a higher (although not significant) level than Control

TABLE 3

NUMBER AND PROPORTION OF SUBJECTS WHO PASSED THE CLASSIFICATORY AND FORMAL LEVELS ON THE TWO-MONTH RETENTION TEST

Test	Treatment Group			
	Exp. 1 (N=28)	Con. 1 (N=29)	Exp. 2 (N=25)	Con. 2 (N=26)
Classificatory	26(.93)	22(.76)	24(.96)	16(.62)
Formal (overall)	13(.46)	2(.07)	13(.52)	2(.08)
Discriminating	27(.96)	23(.79)	24(.96)	16(.62)
Vocabulary	19(.67)	7(.24)	18(.72)	4(.15)
Evaluating	15(.54)	4(.14)	16(.64)	2(.08)
Definition	20(.71)	6(.21)	19(.76)	6(.23)

Group 2. Previous cross-sectional data have indicated that almost all children attain the concept equilateral triangle at the Classificatory level by sixth grade. Therefore, it may be that at fourth grade only a small amount of instruction or interaction with the stimuli (as in a pretest) is needed for some learning to occur.

Overall data for the Formal level reveal differences between experimental and control groups. Analysis of each of the Formal level subtests reveals interesting patterns of scores. Patterns of scores across groups for the Discriminating Attributes subtest approximate closely those for the Classificatory test. This result is not unexpected, since both tests require subjects to visually discriminate perceptible differences among an array of geometric forms. For the remaining three Formal subtests--Vocabulary, Evaluating Examples, and Definition--the patterns of scores appear to be quite different from Discriminating Attributes while quite similar to each other. These three subtests rely more heavily on verbal processes than on pure visual discrimination.

The retention data clearly indicate that many of the students remembered most of what they had learned two months earlier. Performance on the Classificatory test remained over 90 percent for both experimental groups. The significant difference between Experimental Group 2 and Control Group 2 suggests that control subjects did not learn from the experimental subjects over the two-month period. Differences between the experimental and control groups at the Formal level provide further indication of long-term retention. The data in Table 3 reveal that the differences between experimental and control groups on the posttest were also significant on the two-month retention test. The only departure occurred on the Discriminating Attributes subtest, where no pairwise differences were found to be significant. This finding was a result of an increase in performance of both control groups and not due to a decrease in performance of either experimental group. The decrease in overall performance on the Formal test by Experimental Group 1 and Experimental Group 2 (.14 and .12, respectively) was anticipated by the investigators, since a decrease in the number of subjects passing any one of the Formal subtests automatically reduces the number of subjects passing the Formal level.

There are four reasons why some of the experimental subjects did not pass each Formal subtest. First, several students in each class were well below average in reading ability. It was expected that these students would not learn effectively from the experimental lessons because these lessons required students to read independently. A second related problem was the absence of interaction between student and teacher. No new information was provided to the students concerning the content of the lessons. In a more natural setting, teachers would have been able to supplement the lessons with additional direction and knowledge, thereby clearly helping those students with reading difficulties. Third, students were not permitted to be as actively involved with the instructional materials as they could have been. It is felt by the investigators that if the students could have further participated in the construction of

concept examples and attributes, performance on the Evaluating Examples subtest would have been higher. Finally, a great deal of new information was presented to the students in a relatively short period of time.

The results of the present experiment support the hypothesis that an instructional design based on task analysis can be used effectively in developing instructional lessons to accelerate children's attainment of subject-matter concepts. Moreover, the instructional design procedure employed in this study led to an impressive amount of retention over a two-month period.

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